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An overview of the Romanian renewable energy sector

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ABSTRACT

The past 20 years have brought significant changes in the evolution of the energy sector in Romania. Even if it is considered a country with high potential for renewable energies, these are not fully exploited. European Union accession has determined significant changes in energy policy, energy legislation alignment and promotion of renewable energy. In this context, the paper aims to offer a comprehensive overview of the renewable energy sector in Romania. Based on an extensive research of Romanian energy policy and legislation, the article presents the Romanian energy sector and the current status of the main renewable energy sources. The information was gathered from the available data in statistical reports, energy and environment strategies, energy companies' reports, NGO studies and research articles.

Contents

1. Introduction

The high oil prices and volatility have focused the attention of policy-makers on broader issues of energy security. Energy security is the ability of a nation to deliver the energy resources needed to ensure its welfare and implies secure supply and stable prices. Decision about ensuring energy security are always taken in long term, because it implies the implementation of large projects, needing enormous investments. To meet its energy needs, European Union uses mainly primary fossil fuels and heavily depends on imports, with tendency of increasing its import dependence in the long term. The European strategy to decrease the energy dependence rests on two objectives: the diversification of the various sources of supply and policies to control consumption. The key to diversification is renewable energy sources (RES), because they have significant potential to contribute to a sustainable development [1]. Renewable energy (RE) diversification should take into consideration wind, solar, wave, tide, current, biomass, geothermal and hydro energies.

An efficient utilization of renewable resources has a significant potential in both stimulating the economy and reducing pollution. It could boost the economy with direct business benefits, increasing the overall capacity of regional players in enhancing science and technology based development. Despite the immense benefits from utilization of RES, their use is not exploited to the full

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potential due to technical, economic and social constraints [2]. Unlike conventional energy sources, which have benefited from decades of research and development and a well-established industrial base, the modern use of renewable energy is still in its infancy. Experience in recent years suggests that creating an adequate policy and institutional framework can play a crucial role in promoting the use of renewable energy [3]. Thus, many governments started to implement various policies that support renewable generation. One of the key components of any renewable energy policy is setting of renewable energy targets [4]. Some examples of targets are: RES share in electricity production, RES share in primary or final energy supply or consumption, RES share in heat supply, RES installed capacities, the share of biofuels in road transport.

China and India were the first countries that proposed RES targets [5]. Over the time the number of countries adopting RES targets increased. The Renewables Global Status Report [6] released in 2012 shows that at least 118 countries have various renewable energy targets in place. United States doesn't have a national RES target, but 30 states and Washington DC have mandatory targets and other 6 states voluntary targets [7]. California is one of the US states with highest targets: by 2020 the share of renewables in state's electricity should be 33% [8]. In Canada, also, there isn't a national target, but 6 provinces have. In the frame of policies for reducing the nuclear energy, Japan has the goal that until 2030, 25%–35% of total power generation should be delivered from renewable sources [9]. China has the goal of 15% share of final energy to originate from non-fossil fuel sources by 2020 [10]. The Australian target is that by 2020 at least 20% of electricity supply to come from renewable sources [11]. The European Union has adopted a target of 20% share of energy from renewable sources in final consumption of energy [12], with individual member states having individual targets above or below that amount (Table 1).

Table 1
Mandatory national targets for share of energy from renewable sources in final consumption of energy, for year 2020.
Source: European Commission [12].

Country	Target
Belgium	13%
Bulgaria	16%
Czech Republic	13%
Denmark	30%
Germany	18%
Estonia	25%
Ireland	16%
Greece	18%
Spain	20%
France	23%
Italy	17%
Cyprus	13%
Latvia	42%
Lithuania	23%
Luxembourg	11%
Hungary	13%
Malta	10%
Netherlands	14%
Austria	34%
Poland	15%
Portugal	31%
Romania	**24%**
Slovenia	25%
Slovakia	14%
Finland	38%
Sweden	49%
United Kingdom	15%

During the last decades, renewable energy technologies have received political support. If renewable energy technologies have to compete with traditional technologies without additional support, new investments may not take place and the change in the system will be difficult. RES is promoted by various support schemes. Most experience with supporting RES is available in the electricity sector. For example, in Europe, the EU Directive 2001/77/EC [13] required the EU Member States to increase the share of RES-E using national support instruments.

The main RES-E support schemes used around the world are [14]:

- Investments subsidies. Governments may offer subsidies on investment for RES-E technologies in terms of €/kWh or percentage on total investment.
- Feed-in tariffs. Feed-in tariffs stimulate generators of RES-E to introduce electricity into the grid by receiving in exchange a minimum price per kWh produced, the feed-in tariff. As generation costs differ across renewable energy technologies, the feed-in tariff is usually different per technology.
- Tradable Green Certificates (in Europe) and Renewable Portfolio Standards (in US and Japan). Generators of electricity produced from renewable energy sources receive a certificate for each megawatt-hour supplied. Consumers have to purchase certificates in order to cover their target. The price depends on factors like the market demand and supply, the renewable technology used and the vintage of the generation capacities. If the amount of green certificates supplied is low, the price will be higher. A higher market price will be an incentive to produce more renewable electricity [15].
- Tenders for contracts. A public institution invites companies to compete (through tenders) for a specific financial budget or capacity. There are usually separate tenders for different RE technologies. Contracts are awarded to the cheapest bids [15].
- Fiscal instruments: exemption of RES-E from energy taxes, tax refund for RES, lower VAT rates, exemption of investments in RES-E plants from income or corporate taxes.

2. Country overview

Romania, a Latin language and culture country located on the banks of the Black Sea, is the largest country in southeastern Europe and the twelfth-largest in Europe. Romania joined European Union in the second wave, in 2007. The population counted on 2011 census was around 19 million persons [16]. Urban population is estimated at 52.8%, a low level having in mind that in the last decades was a mass migration from rural to urban areas. Expectation of life in 2011 was 69.8 years for males and 77.4 years for females [16].

Romania is a blessed country with a large variety of natural resources: fertile agricultural lands, forests, crude oil, natural gas, large deposits of brown coal and lignite, mineral, salt, gold and silver deposits, hydrological networks. A special category of resources is considered to be the large number of mineral water springs and geothermal water deposits. So, the country has a very good energy and renewable energy potential.

The Romanian landscape is varied and harmoniously distributed: 31% mountains (the Carpathians), 33% hills and tablelands, 36% plains and meadows [17]. To the east, Romania has access to the Black Sea with a coastline of 245 km [17]. Agriculture land is located in the plains and plateaus located in the south, west, southeast and east of the country. Romania has the largest surface of virgin forests in Europe, the Southern Carpathians being the Europe's largest continuous forested area [18].

Romania's climate is temperate-continental with four clearly defined seasons. The summers are very hot and dry, with small amounts of precipitation. Heavy rainfalls and flooding are common in spring. Autumn is a transition season, with long periods of drought alternating with periods of rain. The winters are cold, with fog and sometimes with strong snowstorms. The Carpathians block the Atlantic air masses and the continental influences from Russian plain, determining different climate zones along the country. Thus, the average annual temperature decreases from south (10–11 °C) to the north (8.5–9 °C) [19]. In the south of the country there are over 40 days with temperatures over 35 °C. Precipitation decreases from west (over 600 mm/year in the Western Plain) to east (below 400 mm/year in the Danube Delta) and from mountains (over 1010 mm/year) to plains (500 mm/year in Romanian Plain) [20]. The mean annual rainfall totals 637 mm [20]. The duration of sunshine has a high value in plain areas (2100–2200 hours yearly) and a lower one in mountain areas (1800 hours) [20]. The relief has also a huge impact on the winds blowing. The wind-chill, the Black Sea breeze and the mountain winds present important energy potential. The average wind velocity at the Black Sea coast amounts 5 to 7 m/s, on the top of the mountains 6–10 m/s and on the Dobrogea plateau about 5.5 m/s [20].

The Carpathians are an important watershed for the Romanian hydrographic network, feeding the major rivers of the region. The most important river collector is Danube, which crosses the country in the south on 1075 km length and flows into the Black Sea through a large delta. Other important rivers are Mures (761 km), Prut (742 km), Olt (615 km), Siret (559 km), Ialomita (417 km), Somes (376 km), Arges (350 km), Jiu (339 km), Dambovita (286 km) and Bistrita (283 km) [17]. Beside rivers, there are more than 3,500 lakes and ponds, ranging from the glacial mountain lakes to the saline lagoons on the Black Sea coast. Water resources are irregularly distributed in space. Thus, large and important areas such the plains of Moldova and Dobrogea are poor in water. Variations also occur from year to year, depending on the amount of precipitation, with frequent and intense floods in spring and severe drought in the other seasons.

The relief and climatic conditions determine the vegetation. Forests and other wooded lands areas account 26.2% of the country's area, many of which are in the mountains [17]. Fir, spruce, pine and larch are the most common conifers at altitudes between 1200 and 1800 m, while at lower heights are predominant the forests of beech and oak. Up to 1800 m alpine meadows occupy large areas, used mainly in sheep breeding. In plains and tablelands vegetation consists of bushes and grass. The Danube Delta has 180000 ha of single reed bed and other aquatic plants [17].

3. Energy sector overview

Romania has very good energy resources, and as consequence has the potential to be energy self-sufficient for several decades. In terms of fossil fuels, it possess more than other European countries, having domestic sources of natural gas, crude oil and coal (mostly lignite) [21]. Therefore, its energy dependency is lower than most European countries, reaching a value of 21.34% for all energy products in 2011, a good figure judged in correlation with the EU-27 mean of 53.83% [22]. Although Romania has 5% of Europe's crude oil resources and the biggest gas and shale reservoirs in the CEE region (together with Poland and Ukraine), the country imported about 17% of its gas consumption in 2010 (98% of imports come from Russia) and 66% of its oil [23,24]. To decrease this dependence on fossil fuels, the Romanian government has set ambitious goals. By 2020, 24% of final energy consumption should be covered from renewable energy sources, in conformity with European Union requirements (Table 1).

Romanian energy requirements are satisfied by national sources and those sourced from global energy markets. Presently, domestic production supplies around 70% of the primary energy demand. Fossil fuels and hydropower (mainly large scale) are the country's primary sources of energy (Fig. 1). The country also has placed an increasingly emphasis on nuclear energy. Almost 19% of its electricity (3.03 Mtoe in 2010) is generating by two nuclear reactors from Cernavodă Nuclear Power Plant, the only one of its kind in Romania [25].

Most hydro energy is produced in dams with storage ponds, so that electricity generation may vary according to the precipitation. Thermal capacity is around 45% coal, around 45% gas, and 10% mostly black oil [27]. Most of thermal plants were built between 1960 and 1970, 60% of the thermal capacity being over 20 years old. More than 50% of the thermo generation is based on heat and power cogeneration plants (CHP) [27]. Most of the CHP plants are obsolete and have very low thermodynamic efficiencies, so in the last decade, there was decommissioned nearly 3000 MW of thermal generation capacity [28].

Although Romania has a high potential of renewable energy sources, in 2010, the RES share in final energy consumption was 23.4%. Anyway, Romania ranked the second place in the European Union concerning the share of energy from renewable sources in gross final consumption between 2006–2010 [22].

For years, the intensive industrial development of Romania was made through systematic exploitation of natural resources without taking into account the environmental effects [29]. The former communist regime stimulated the development of a highly industrialized economy, based on energy intensive industries, leading to high levels of energy consumption. After the fall of the communist regime, in the 90s, the transition from a centralized economy to a market economy has been accompanied by a decreasing energy demand [30].

The evolution of energy production and consumption was influenced by the fluctuations of the Romanian economy. When the economy expanded or contracted, the energy demand increased or decresed. In the last decade Romania's demand for electricity has been mostly constant, the electricity supply being dominated by thermal-electric sources, with hydroelectric power supplying one-third of the generation [31]. A historical summary of Romania's primary energy production and consumption between 1999 and 2010, and the mix share are shown in the Table 2.

In the same time was registered an important decrease of energy intensity as result of the energy policy measures and energy efficiency programmes implemented. Between 2000 and 2010 the energy intensity decrease was of 68% [32].

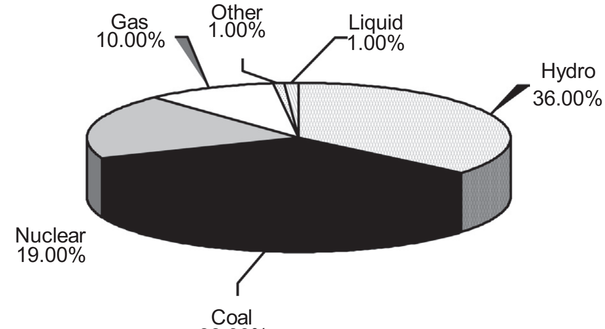


Fig. 1. Structure of the total primary energy supply (2010).
Source: ANRE [26].

Table 2
Primary energy production and consumption mix share between 1999 and 2010.
Source: ANRE [26] and ICEMENERG [31].

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total energy consumption (*ktoe*)	**36,556**	**36,374**	**37,971**	**36,480**	**39,032**	**39,018**	**37,932**	**39,571**	**39,159**	**39,799**	**34328**	**34817**
Coal	6,853	7,475	8,169	8,812	9,509	9,172	8,742	9,540	10,064	9,649	7436	6911
Oil	10,235	9,808	10,804	9,371	9,088	10,092	9,163	9,840	9,658	9,719	8239	8417
Natural gas	13,730	13,679	13,315	13,326	15,317	13,766	13,820	14,308	12,862	12,476	10642	10897
Hydroenergy	1,503	1,212	1,172	1,136	962	1,320	1,489	1,212	1,195	1,115	1164	1573
Nuclear energy	1,274	1,338	1,335	1,352	1,203	1,360	1,362	1,381	1,890	2,752	2881	2850
Other fuels	127	92	1034	115	93	93	88	87	194	352	198	161
Wood and agricultural waste	2,817	2,763	2,314	2,351	2,844	3,134	3,185	3,185	3,275	3,710	3742	3982
Renewable energy	17	7	7	17	18	81	82	18	21	26	25	26
Total primary energy production (*ktoe*)	**27,890**	**28,191**	**29,022**	**27,668**	**28,192**	**28,095**	**27,154**	**27,065**	**27,300**	**28,779**	**28,034**	**27,428**
Coal	4,644	5,601	6,239	6,117	6,636	6,193	5,739	6,477	6,858	7,011	6,476	5,903
Oil	6,244	6,157	6,105	5,951	5,770	5,592	5,326	4,897	4,651	4,619	4,390	4,186
Natural gas	11,192	10,968	10,889	10,384	10,529	10,196	9,536	9,395	9,075	8,982	8,964	8,705
Hydroenergy	1,574	1,272	1,284	1,381	1,141	1,421	1,739	1,580	1,370	2,339	1361	1769
Nuclear energy	1,274	1,338	1,335	1,352	1,203	1,360	1,362	1,381	1,894	1,894	2881	2850
Wood and agricultural waste	2,820	2,762	2,130	2,351	2,903	3,160	3,229	3,235	3,304	3,750	3,838	3,900
Other fuels	125	86	103	115	92	92	87	82	127	158	98	90
Renewable energy	17	7	7	17	18	81	82	18	21	26	25	26

Following a public electrification programme the power supply coverage has increased to 99% in the urban areas and 95% in the rural areas and only isolated communities are not connected to electricity networks [33]. The rural electrification programme was carried out between 1950 and 1970 and consequently most of the networks are old and need upgrading. Therefore the supply of electricity in rural areas does not guaranty an adequate quality, because of the load variation of the electric power in the network or the frequent voltage drops [33]. A problem for the Romanian energy system is represented by the distribution grid, many transformer stations and substations having a high degree of depreciation. The situation is better for the transmission network.

The most of Romanian larger towns have district heating systems supplied by heat and power cogeneration plants. Energy losses in these systems are high due to poor pipe insulation, corrosion and lack of maintenance, so heating bills for households increased very much. More over, many of the centralised heating systems are unable to meet peak demand, and consumers situated at the end of the district heating network receive heat and hot water at low levels of quality. In these circumstances, many consumers have chosen to disconnect from the district heating system. They have chosen various domestic solutions from gas heating systems to wood stoves. As result, the distribution system is confronting with imbalances that reduce the overall system performance and efficiency. This is reflected in a low quality of services for the consumers connected to the district heating system [34].

The natural gas supply network is developed mainly in urban areas. Although in the last years the networks have been extended especially in rural areas surrounding the big towns only 5% villages are connected to the natural gas network. Under these conditions more than 90% of rural households uses wood stove as the main heating system and 43% are obliged to use forestry products for cooking [33].

Since 1990 Romania has been connected to the international markets and the energy sector benefited from different grants, loans and technical assistance programs [35]. The necessary investments were supported from state funds and European funds agencies, while loans have been arranged through the major international financial institutions: European Bank for Reconstruction and Development and the World Bank. Other sources of investments were the bilateral energy projects developed in cooperation with various countries such as Denmark, the Netherlands, France and the United States [19]. Much of this assistance has been motivated by the need to prepare Romania for accession to the European Union.

Table 3
Energy potential of renewable energy sources.
Source: ANRE [26].

Renewable energy source	Annual energy potential	Economic energy equivalent (ktoe)	Application
Solar energy			
- thermal	$60*10^6$ GJ	1,433.0	Thermal energy
- photavoltaic	1,200 GWh	103.2	Electrical energy
Wind energy	23,000 GWh	1,978	Electrical energy
Hydro energy (total)	40,000 GWh	3,440.0	Electrical energy
- under 10 MW	6,000 GWh	516.0	Electrical energy
Biomass	$318*10^6$ GJ	7,594.0	Thermal energy
Geothermal energy	$7*10^6$ GJ	167.0	Thermal energy

After becoming Member State of EU in 2007, the whole European legislation in the field on energy has to be transposed into national legislation. Based on EU energy policy, the government approved the Energy Strategy and the and National Renewable Energy Action Plan [36]. The strategy defines the long-term development of the energy sector, highlighting the importance of energy efficiency, renewable energy sources and modernization of the country's infrastructure.

Like other strategic industries, the energy sector has been gradually restructured and has been subject to institutional and market liberalization reforms. As consequence, some distribution companies were privatized, allowing big international players to enter the Romanian market (Enel, E.ON, CEZ, Gdf Suez) and to create a framework for continuous investments in the field, leading to the improvement of the quality of services.

As a conclusion, the key features of the energy sector in Romania are low energy efficiency (both in production and consumption), low levels of investments, the need for modern technologies, as well as irrational consumption of energy.

4. Current status of the Romanian renewable energy

Due to availability of natural resources, the use of renewable energy sources to satisfy different human needs has long tradition in Romania. For centuries Romanians have been used wind and water to put in force mills, wood and solar energy to heat water and houses. The concerns for promoting renewable energy are dated since 1970s, Romania being a pioneer in this field [37]. One effect of the former communist state collapse was the decrease of public investments in the field, leading to the stagnation of the renewable energy sector development. In recent years due to impulses received from the European Union, Romania has relaunched the exploitation of renewable energy sources.

Being endowed with so many natural resources, Romania is a country with a high renewable energy potential. The type of resources and the energy potential of each are summarized in Table 3. An important problem is determined by the gap between the theoretical potential and the technical and economical feasible potential. Thus, the RES primary production in 2011 was 5028 ktoe, divided in 3618 ktoe biomass energy, 1266 ktoe hydro enegy, 120 ktoe wind energy and 24 ktoe geothermal energy [22].

Romania is pursuing renewable energy sources in three different directions:

Electricity (RES-E). The renewable energies used to produce electricity are wind, hydropower, solar photovoltaic and biomass. In 2011 the electricity produced from renewable sources achieved 20673 GWh [26] leading to a share of RES-E in total gross electricity consumption of 27.05% [22]. The number of RES-E licensed producers in 2011 was 82 (of which 42 use wind energy, 32 hydro energy, 4 biomass energy and 4 photovoltaic energy) [26]. Hydro plants produce a very high share of RES-E (Table 4).

Heating/cooling (RES-H). As not all renewable sources have the same potential to provide in heat, the Romanian renewable energies most suited for heating and cooling are: biomass, geothermal and solar resources. Table 5 shows the share of each technology in RES-H production in 2010. Biomass contributes considerably to Romania's heat production and consumption. These levels are the result of the high use of forestry products for heating. About 95% of the biomass resources are used in private households for heating, cooking and hot water preparation, the remaining being used by industry [30]. Even Romania was one of the first countries in the world which implemented large scale programs for solar applications, presently, the solar energy is the lowest developed field from all renewables and the new investments are very few. Thus, the share of solar energy in RES-H is almost negligible. Romania has significant geothermal resources whose exploration began in the 1960s. The main uses are in district heating, health and recreational bathing, greenhouse heating and aquaculture. The geothermal resources aren't exploited at their full potential because of the higher costs of the technologies required and lack of funds

Transportation (RES-T). The country's intention to comply with the Kyoto Protocol require, among other measures, an increased use of biofuels for transport. In Romania, biofuels are obtained by processing the rape, corn, sunflower and soybean crops. Although Romania has a huge potential in terms of energy crop production, biofuels production registered very low levels (163 ktoe) [33].

Table 4
RES-E production (2011).
Source: ANRE [26].

RES-E technology	GWh
Photovoltaics	2
Solar Thermal	0
Wind on-shore	290
Winf off-shore	0
Hydro large scale	18,992
Hydro small scale	1,273
Biomass	118
Biogas	0
Geothermal energy	0
Total	**20,675**

Table 5
RES-H production (2010).
Source: ANRE [26].

RES-H technology	ktoe
Biomass	415
Solar thermal	5
Geothermal energy	18
Renewable energy from heat pumps	8
Total	**446**

The share of renewable sources in primary energy consumption and in electricity consumption is significantly above the EU average (Table 6). Although these levels are significantly higher than the average of EU-27, the energy is obtained mainly from conventional renewable sources (large hydro and biomass) rather than through green renewable sources. [27].

In order to promote the production of energy from renewable energy sources, Romania implemented the National Renewable Energy Action Plan. As a result of various measures for promotion of RES, the renewable energy primary production increased in time (Table 7).

Some key measures to support the increasing use of renewable energy are: the creation of a legislative framework for renewable energy, the development a functional system of incentives, the use of environmental funds and the development of a national strategy for renewable energy. Whilst most European countries have implemented feed-in tariff polices, Romania adopted a quota system with tradable green certificates. A green certificate represents an additional income received by producers for the delivery of renewable energy in the grid. Since October 2005, the certificates are being traded at the electricity market administrated by OPCOM. For each MWh generated from RES each producer receives a number of green certificates. The support scheme is applied between 3 and 15 years, depending on the technology used. Solar energy plants receive six certificates, hydropower plants with capacity up to 10 MW receive 3 certificates if the plants are new, 2 certificates if the plants are refurbished and 1 cerficate if plants are old and are not refurbished [39]. For geothermal, biomass, bioliquids, biogas are issued 2 green cerfificates [39]. The range of trading for green certificates was established between 27 and 55 euro, indexed annually since 2011, according to the average annual inflation index of the previous year. The share of each type of RES in the total number of green

Table 6
Share of renewables (2010).
Source: Eurostat [22].

Indicator	Romania	EU-27
Share of renewables in gross final energy consumption	23.4%	12.5%
Share of electricity generated from renewable sources	34.18%	19.94
Share of renewable energy sources in heating and cooling	27.2%	14.3%
Share of renewable energy sources in transport	3.2%	4.7%

Table 7
Renewable energy primary production (ktoe).
Source: Eurostat [22].

Renewable energy primary production:	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Solar energy	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass and renewable waste	2820	2763	2130	2351	2844	3160	3229	3235	3325	3832	3915	3949	3618
Hydro	1573	1271	1283	1380	1140	1420	1737	1578	1373	1479	1336	1710	1266
Geotermal	8	7	5	17	18	13	18	18	20	25	24	23	24
Wind	0	0	0	0	0	0	0	0	0	0	1	26	120
Total	**4401**	**4041**	**3418**	**3748**	**4002**	**4593**	**4984**	**4831**	**4718**	**5336**	**5276**	**5677**	**5028**

Table 8
Green certificates issued for E-RES production (2012).
Source: ANRE [26].

RES type	Share (%)
Hydro	17.60
Wind	74.61
Biomass	7.53
Solar	0.44
Geothermal	0

Table 9
Renewable indices for Romania, February 2013.
Source: Ernst & Young [40].

Index	Score	Rank
All renewables	46.8	13
Wind index	54	10
Solar index	41	24
Biomass	45	15
Geothermal	42	10
Infrastructure	48	20

certificates issued for E-RES production in 2012 is presented in Table 8.

In the RES-H field the support mechanism is the so-called CASA VERDE (Green House) program, focused on building heating systems using RES. The program provides capital grants for RES heating systems replacing conventional systems. Thus, various solar, biomass and geothermal application, which bring improvements in environmental protection are eligible for grants.

The support mechanisms to promote biofuels (RES-T) are a quota system and the suspension of the exemption from excise tax for biofuels, which operated until 1 March 2011.

The legislation also offers other various tax incentives for renewable energy producers:

- Electricity produced from RES is exempt from excise duties;
- Accelerated depreciation for tax purposes for technologies used in energy projects using renewable sources;
- Tax exemptions for renewable energy investments;
- Reduced costs for the authorizations and licenses in the RES field;
- Reduced financial contributions from the state budget if new jobs are created in the field;
- State guarantees for renewable energy investments.

Since 2003, Ernst & Young has been releasing quarterly data that ranks national renewable energy markets and infrastructures [40]. In the latest top, released in February 2013, Romania achieved the 13th position, as a result of its fast-growing wind market. Table 9 presents the indices obtained by each renewable.

A sustainable energy system has to minimise the environmental impact of energy production and use. This requires cleaner energy sources and the reduction of the adverse effects of fossil fuels. In this frame, the renewable energies have an important role to play in meeting future energy needs of Romania, so in the following are presented the main RES the country use.

4.1. *Hydro energy*

Hydro power is the energy created from the force of falling or flowing water (rivers, dams and waterfalls). This kind of energy has many advantages: it can be stored (unlike the sun or wind), there isn't any fuel purchase costs, it is a multiple-use resource, it is less expensive than mining fossil fuels and does not contribute to the greenhouse effect. The large hydro power plants require the construction of dams, disrupting the river flow and fish migration and generating various environmental damage. In small hydro projects the river flow is diverted through a large pipe to a downstream turbine that generates electricity, so the environmental effects are lower.

The Romanian potential for hydroelectric power is great, the country having many rivers. The first hydropower plant in Romania was built in 1960 on the river Bistrita. Since then, hydropower energy has been considered a very important energy source. Romania has the largest hydropower plant from Europe, Portile de Fier, on the Danube river. In addition to Portile de Fier, there are other eleven hydroelectric facilities with capacities of at least 100 MW each, and many medium-sized facilities of at least 30 MW, exploiting the power of the following rivers: Olt, Lotru, Bistrita, Somes, Dragan, Arges, Dambovita, Raul Targului, Sebes, Raul Mare, Cerna, Bistra, Buzau, Motru. The harnessed technical hydropower potential in Romania is 36 TWh/year [41]. The harnessed economic hydropower potential is estimated at 23–25 TWh, with an installed capacity of about 8000 MW [41].

Since 2008, the Romanian legislation offers incentives for the production of energy in small hydro capacities, leading to a boom in the construction of small hydropower plants. Until the end of 2012 almost 300 projects have been approved for the construction of 536 units of up to 10 MW, the most placed on the Southern Carpathians [26]. The financing was assured by bank loans (including EBRD) and EU Structural Funds.

According to ANRE, in 2010 the production of hydro energy in Romania was about 20625 GWh, with a share in electricity generation of 32.4% [26]. The most of electricity was generated through large-scale hydro power (Table 10). The largest hydro energy producer is Hidroelectrica. In 2010 Hidroelectrica had a total installed power of 6438 MW divided into 247 groups with instaled power more than 10 MW (in 106 plants), 46 groups between 4 MW and 10 MW (in 23 plants) and 285 groups with installed power less than 4 MW (in 139 plants) [26]. Small hydro plants in Romania account a total capacity of 1125 MW [26], but this capacity is not entirely functional, leaving the high potential of small-scale hydropower somewhat untouched.

Table 10
RES-E produced by hydro plants (2010).
Source: ANRE [26].

Technology	GWh	%
Hydro over 10 MW	18,992	92.08%
Hydro under 10 MW	1,273	6.17%
Total hydro	**20,625**	**100%**

Table 11
Evolution of the installed power in wind power plants.
Source: European Wind Energy Association [42].

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Installed power	0	0	2	8	11	14	462	982	1905
Onshore (MW)	0	0	2	8	11	14	462	982	1905
Offshore (MW)	0	0	0	0	0	0	0	0	0

4.2. *Wind energy*

Wind energy is a clean renewable energy source. Using special turbines the power of wind is converted in electricity. The investments costs for developing wind energy projects are high, but the exploitation costs are low. Thus, the access to initial funds, subsidies, tax reductions or low interest loans are important advantages in the development of wind energy projects.

Large areas with wind speeds over 11 m/s and low population were identified in the southeast of the Romania, near the Black Sea and Danube Delta, in Constanta and Tulcea counties [19]. Other regions with a high wind power potential are Moldova, in the east of the country and Caraş Severin, in southwest [19]. Thereby, the Romania's potential in wind energy is very high, being considered the highest in South Eastern Europe and the second in Europe.

The utilization of wind energy has a long tradition in Romania. In some locations from Moldova, Dobrogea and Danube Delta windmills from the 19-century used for the milling of grain and water pumping are still in operation [35]. The use of wind power for the production of electricity has been recently initiated in Romania and is the most dynamic field from all renewables. The evolution of the installed power in wind farms is presented in Table 11. Following the policies for stimulation the wind energy, the attractiveness for investments in wind energy projects increased. Thus, Ernst & Young [40] ranked in February 2013 the Romanian wind energy market on 10th position in the world. At the end of 2012 the installed wind capacity was 1905 MW [42], the most of capacities being installed after 2010. The biggest investment in the field (600 MW) is at Fantanele and Cogeleac wind park, in the southeastern region of Dobrogea, 17 km from the Black Sea [38].

4.3. *Solar energy*

Several technologies are presently used to harness the sun's radiation into useful energy in the form of heat (solar heating) or electricity (photovoltaics). Photovoltaics (PV), which convert sunlight direct into electricity, is the single technology used in Romania. The country is not prepared for complicated technologies using Concentrated Solar Power (CSP), which uses mirrors and reflectors to create a beam of energy from the sun's rays.

In Romania the annual solar energy flow ranges between 1000–1300 kWh/m^2/year in more than half of the country [38]. This climate allows the operation of solar panels from March until October, with a conversion efficiency between 40% and 90% [41]. Thus, an important solar potential exist. The most important regions of Romania with high solar potential are the Black Sea coast, Dobrogea and a great part of the Romanian plain, with an average of 1600 kWh/m^2/year [41].

Romania's experience in solar energy represents a competitive advantage for the future development of this area, the country being a pioneer in this field. Between 1970 and 1980 were installed around 800000 m^2 of solar collectors, that placed the country third worldwide in the total surface of photovoltaic cells [38]. The research efforts generated an important human and infrastructure potential. Between 1984–1985 was achieved the peak of solar installations, but after 1990 unfavorable macroeconomic developments led to the abandonment of the production and investments in the solar energy field [38]. Today about 10% of the former installed collector area is still in operation [38].

Electricity production from solar photovoltaic was around of 1 GWh in 2010 and 2 GWh in 2011. In 2011 the photovoltaic power per inhabitant in Romania was estimated at 0.1 Wp, very low comparing with 102.2 Wp/inhab at European Union level [43].

Although sunlight is free, the technologies necessary for conversion in power require large costs. Thus, the state should deliver a strong and reliable subsidy scheme to support the development of the field. Since 2011, when the new RES law entered into force, providing six green certificates for each MWh produced from solar energy, the field has become an attraction both for Romanian and foreign investors. Many photovoltaic parks were developed in various locations of Romania and others are in the planning phase. Many local councils are willing to join with international developers with the goal to build solar power parks. However, the number solar projects is insignificant, the amounts allocated until 2012 being around 70 million Euro, compared to the 3 billion Euro attracted by wind projects [26].

4.4. *Biomass energy*

Biomass means "no fossilized and biodegradable organic material originating from plants, animals, and microorganisms" [44]. So, biomass energy is generated using a variety of sources: forest wastes, energy crops, agricultural waste and household waste, being the most easily accessed and affordable of all renewable energies. In fact, biomass is the world's fourth largest energy source worldwide, following coal, oil and natural gas [45]. Typically, biomass energy production can be divided in 2 categories: biopower (biomass is burned to generate heat and electricity) and biofuels (biomass is transformed into liquid fuels, used for the replacement of petroleum products in transport).

Romania has forests that cover more than a quarter of the country and large agriculture lands (43.4% of country's surface). As the biomass potential depends to a great extent on forest and land availability, Romania has a good biomass energy potential, estimated at about 7594 ktoe per year [46]. Thus, biomass potential accounts 51.61% of the total Romanian RES potential (Table 3). Potential resources are forestry and firewood wastes, wood-sawdust wastes, agriculture or crop wastes (animals, vegetable), domestic waste and biogas. Even the Romanian biomass potential is high, there is a large amount of biomass still unused. Table 12 shows the biomass potential in Romania, splitted on biomass types.

Firewood and wood waste are predominant in Carpathians, agricultural waste in the South Plain, Moldova and Sub Carpathians and biofuels in the South plain. Table 13 shows the biomass potential in Romania, by region.

The use of forest products for heating has a long tradition in Romania. For centuries, wood continues to be the primary fuel used for heating and cooking in rural areas. In addition to the use of traditional stoves, several biomass district-heating plants based

on residues from wood processing, with capacities between 1 and 7 MWth, were developed in small towns and villages from Carpathians and Sub-Carpathians areas [47]. In the last years, biomass has also been used for thermal and power production within cogeneration power plants [48]. The share of district heating in the total amount of biomass used for energy production is very small, around 1.8%. [48].

Agricultural wastes represent another segment of the biomass. Although Romania has a wide variety of crops, only a few of them are used for energy production, mainly because of technical limitations in the conversion process. The main sources of energy crops are:

- oilseed crops (rape, sunflower and soy) used for biodiesel production
- sugar and starch crops used for bioethanol production (wheat, corn, maize, barley, potatoes and sugar beet)
- woody crops (willow) used for heat and power production.

Biomass represents 99.5% of renewable energy used for heating, while biomass contribution to renewable electricity generation was insignificant [47]. The statistics show that 54% of the heat produced on biomass basis is obtained by burning wood wastes and 46% is derived from agricultural wastes [49]. Energy crops are used mainly for biofuels production.

Unfortunately, in Romania there aren't many incentives for the use of modern biomass technologies for thermal and electricity generation. Thus, the analysis of the last available data shows a total of 3356 ktoe/year biomass final consumption, divided into 2840 ktoe/year consumption in old rural traditional stoves and 516 ktoe/year consumption in industry and tertiary sector [48]. Table 14 presents the share of each biomass technology for energy production in 2010.

Concerning the biofuel and biogas fields, Romania is practically at the beginning. In 2007 has started the local production for biodiesel and bioethanol. The potential of biodiesel capacities is around 400000 tones/year for biodiesel and 120000 tones/year for bioethanol [36]. Romania's potential to supply the raw materials necessary for biodiesel production (sunflower, soy, rape) is around 550 thousand tones/year, and for bioethanol production around 520 thousand tones/year (splitted in 390 thousand tones/year from corn seed and 130 thousand tones/year from wheat germs) [46]. Rape is the most promising crop for biofuel production [51].

In 2011 around 161000 tones of biofuels were produced in Romania, representing 3.2% of all fuels used in transport [38]. The Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport [51] has been included in the national legal frame and according to the law the biofuels has to replace diesel and petrol fuels up to 10% by 2020.

4.5. Geothermal energy

Geothermal energy is the energy stored in the Earth's crust. Descending deeper inside the earth's crust, the temperature and pressure rise and geothermal energy can be used more efficiently. Thus, the potential of geothermal energy is huge, but only a part of it could be used. Geothermal resources exist in low-enthalpy forms (corresponding to temperatures less than 200 °C) used mainly for direct heating applications and high-enthalpy forms (corresponding to temperatures higher than 200 °C) suitable for electricity generation. Generally, high-enthalpy resources are available in areas with volcanic and geyser activity, whereas the rest of forms are low enthalpy resources.

Romania, together with other neighboring countries (Hungary, Serbia) has important low-enthalpy geothermal resources suitable for direct heating applications, with major potential locations in the Western Plain (4300 TJ/year potential energy production), South Plains (720 TJ/year potential energy production) and Southern Carpathian regions (270 TJ/year potential energy production) [38]. Unfortunately many geothermal sites are used solely for recreation, because Romania possesses mostly low-enthalpy geothermal resources.

Table 12
Biomass potential.
Source: ENERO [46].

Energy potential	Ktoe/year
Waste from forestry exploitations and firewood	1175
Wood waste –sawdust or other wood waste	487
Agricultural wastes	4799
Biofuels	588
Urban household waste	545
Total	**7594**

Table 14
Biomass technology for energy production in Romania.
Source: METBE [50].

Technology	ktoe	%
Solid biomass residential stoves/boilers	2840	84.6
Solid biomass local boilers & DH	56	1.7
Solid biomass electricity CHP	2.4	0.1
Solid biomass heat CHP	2.6	0.1
Co firing biomass power	1	0
Co firing biomass heat	0	0
Biogas electricity CHP	1.7	0.1
Biogas heat	1.9	0.1
Municipal waste electricity CHP	0	0
Municipal waste heat	0	0
Bio-fuels	450	13.4
Total	**3356**	**100**

Table 13
Biomass potential *in Romania by region* (*TJ*).
Source: ENERO [46].

Region	Waste from forestry exploitations and firewood	Wood waste –sawdust or other wood waste	Agricultural wastes	Biofuels	Urban household waste	Total
Dobrogea	451	269	13,422	1,477	910	16,529
Moldavia	1,728	802	37,071	2,462	2,370	44,433
Carpathians	19,552	8,049	17,506	1,231	1,640	47,978
Transylvanian Plateau	8,721	3,482	12,956	2,954	2,740	30,853
West Plain	8,721	3,482	12,956	2,954	2,740	30,853
Subcarpathians	13,034	5,366	40,849	3,693	6,570	69,512
South Plain	2,133	861	54,370	8,371	6,750	72,485
Total	**49,241**	**20,432**	**200,935**	**24,620**	**22,805**	**318,033**

In fact, the use of thermal springs in Romania has been known since the Dacian times, the Romans being the first to exploit them in an organized manner in the famous health spas: Geoagiu, Herculane and Felix. In time were developed around 38 thermal spas [52], Romania being one of the European countries with greatest reserves of thermal springs.

Well-funded geological exploration carried in Romania between 1962 and 1965 have identified 9 geothermal areas (Oradea, Baia Sprie-Cavnic, Toplita, Miercurea-Ciuc-Jigodu, Geoagiu, Herculane, Cozia-Calimanesti, Mangalia, Bucuresti), mostly located in Transylvania. Over 250 wells have been drilled, proving the existence of low enthalpy geothermal resources with temperature of 40–200 °C [53]. Romania's highest enthalpy geothermal resource of 200 °C was identified at Tusnad Bai [38]. The temperature level for the resources located in the western part of the country is low, between 30° to 90 °C. Thus, the geothermal energy is not proper for electricity generation. Anyway, in November 2012 was started the first Romanian power plant based on geothermal water in Oradea. The main use of geothermal energy is for therapeutic and recreational purposes, heating and preparation of domestic hot water, greenhouses heating, soil heating, timber drying, crops drying, milk pasteurization, aquaculture, ceramics drying, etc. Beius is the first and unique Romanian city heated integral with geothermal energy, the works being finalized in September 2012.

Table 15 shows the distribution of geothermal energy for direct use in 2010 [38].

Table 15
Distribution of geothermal energy for direct use.
Source: IGA[54].

Field of use	MWt	%
Individual space heating	13.28	8.67%
District heating	58.95	38.47%
Greenhouse heating	4.18	2.73%
industrial process heat	0.75	0.49%
Agricultural drying	1.40	0.91%
Geothermal heat pumps	5.5	3.59%
Fish farming	4.50	2.94%
Bathing and swimming	64.68	42.21%
Total	153.24	

The most of geothermal projects currently operating in Romania are of low efficiency and obsolete in technology, infrastructure and equipments. The exploration of deep resources implies significant costs and risks, so only about 30% of the resources identified and confirmed by geothermal wells are in use [52]. In addition, the legislation in the field of geothermal energy is vague. The national energy strategy estimates that the use of geothermal energy shall extend in the following years but only for heating purposes. Another obstacle is the lack of incentive policy for the implementation of geothermal projects.

5. Conclusions

Pollution, emissions of greenhouse gases, rising energy demand and an increasing dependence on imports are important energy problems for any country. Renewable energy sources such as biomass, hydropower, wind, solar and geothermal represent the main viable solution for a sustainable future. As Romania is endowed with many natural resources, the potential of renewable energy sources is high, and theoretically can meet many of the country's energy demand. This relatively high potential can't be fully exploited due to high levels for the necessary investments, technological limitations, dispersed location of resources and environmental restrictions.

Romania has a higher share of renewable energy sources in total final consumption than other European countries, and in the last years this trend is growing. The Romanian state assumed towards European Union an increase of the energy generated from renewable sources to 24% in 2020. In order to reach this target Romania needs to exploit a big part of its RES potential. The total expected contribution of each renewable to meet the 2020 targets is presented in Table 16.

Investing in renewables would have a direct impact on the Romanian economy mainly through the contribution to the state budget, creation of new jobs, stimulation of the local production. At the same time, the use of renewable energy resources available shall contribute to the integration of certain isolated areas in the economic circuit.

Romania has to intensify the actions related to the use of renewable resources and to promote environmentally methods for the production, distribution and use of energy, aiming to minimize the adverse effects on environment. The success of these policies

Table 16
Estimation of total contribution (installed capacity, gross electric generation) of each renewale energy to meet the binding 2020 targets.
Source: ANRE [26].

	2013		2014		2015		2016		2017		2018		2019		2020	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Hydro	6857	17624	7087	18191	7287	18679	7387	18904	7452	19063	7513	19214	7621	19491	7729	19768
< 1 MW	76	114	82	123	9-	135	95	143	100	150	103	155	106	159	109	164
1 MW-10 MW	461	888	505	973	547	1054	592	1141	602	1160	610	1175	615	1185	620	1195
> 10 MW	6320	16622	6500	17095	6650	17490	6700	17621	6750	17753	6800	17884	6900	18147	7000	18410
Geothermal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Solar	78	100	113	140	148	180	183	220	200	246	220	271	240	295	260	320
Photovoltaic	78	100	113	140	148	180	183	220	200	246	220	271	240	295	260	320
Concentrated solar power	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind power	**2450**	**4634**	**2880**	**5952**	**3200**	**6614**	**3400**	**7271**	**3600**	**7668**	**3750**	**8020**	**3900**	**8230**	**4000**	**8400**
Onshore	2450	4634	2880	5952	3200	6614	3400	7271	3600	7668	3750	8020	3900	8230	4000	8400
Offshore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	**250**	**1200**	**340**	**1640**	**425**	**2050**	**510**	**2450**	**540**	**2600**	**585**	**2720**	**590**	**2850**	**600**	**2900**
Solid	200	960	250	1200	300	1450	350	1680	370	1780	385	1855	400	1930	405	1950
Biogas	50	240	90	440	125	600	160	779	170	820	180	865	190	920	195	950
Bioliquids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**9635**	**23558**	**10420**	**25923**	**11060**	**27523**	**11480**	**28845**	**11792**	**29577**	**12048**	**30225**	**12351**	**30866**	**12589**	**31388**
of which CHP	250	1200	340	1640	425	2050	510	2450	540	2600	565	2720	590	2850	600	2900

will depend largely on the ability of decision makers to create a welcoming environment for new investments in the field.

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